Weatherwise

Hailstones and Hailstorms

Activities of the Geophysics Research Division, AFCRC

A Fire-Whirlwind of Tornadic Violence

The Hennepin County Tornado

Floods and Tornadoes Mark Early Spring

The Santa Ana

Vol. 5, No. 3, June, 1952

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Managing Editor* — CHARLES A. FEDERER, JR., *Editor*
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ERIC SLOANE, *Art Director*

AMATEUR WEATHERMAN'S ALMANAC

A new annual publication for the amateur weatherman, to be issued shortly by WEATHERWISE, will bear the above title. Its first part will contain a month-by-month review of the weather events of the past year, 1951 in the first volume, with special accounts of the most interesting features of the meteorological calendar. This section will also present 1951 monthly temperature and precipitation statistics for about 200 locations in the United States. The monthly normals for the same locations will be included.

The second part of **Amateur Weatherman's Almanac** will contain instructions for the layman that will enable him to begin weather observing and forecasting without the use of elaborate equipment or intricate information. This section will include, in addition to instructions, 12 monthly forms for recording one's observations in the form of a log. Hints will be given for using these local observations to acquire a facility at forecasting the local weather.

The **Almanac** will be published about July 1st, but in coming years, early in February, as soon as the previous year's climate statistics can be tabulated. The **Almanac** may be ordered from WEATHERWISE, Franklin Institute, Philadelphia 3, Pennsylvania, for one dollar.

MEETINGS OF THE AMS

The 116th national meeting of the American Meteorological Society is scheduled to be held June 16-18, in conjunction with the 33rd annual meeting of the American Association for the Advancement of Science, Pacific Division. All sessions for meteorology under the sponsorship of the Oregon State College branch of the AMS will be held at Oregon State College, Corvallis, Oregon. The technical sessions will include radiation, atmospheric motion, synoptic meteorology, and weather modification processes and evaluation. The complete program with abstracts appears in the March, 1952, **Bulletin** of the AMS.

The 117th national meeting will be held July 1-3, in Buffalo, New York. All sessions are to be at the Hotel Statler, where a block of rooms is being held for AMS members. At a joint session with the Institute of Aeronautical Sciences on July 2nd, Jerome Lederer, director of the Guggenheim Safety Center at Cornell University, has been invited to present a paper on "Flight Safety in Relation to Weather." P. D. McTaggart-Cowan, Canadian Meteorological Service, will be the banquet speaker on July 2nd. The chairman of the committee for this meeting is Dr. Seville Chapman, Cornell Aeronautical Laboratory, who is being assisted by members of the local branch of the AMS in Buffalo, the Western New York Weather Society. The complete program with abstracts is printed in the April, 1952, **Bulletin.**

Both the June and July programs may be obtained as separate reprints from the executive secretary of the AMS.

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Cover: Hailstones as large as hen eggs fell on Columbia, South Carolina, on April 27, 1950. Photograph by Munn-Teal Studio. (See page 51.)

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The risk of raising crops is increased considerably in areas where they are subject to damage by severe hailstorms. Here a farmer dejectedly surveys a ruined tobacco crop at Greenville, Tennessee. Photo by Rain and Hail Insurance Bureau, Chicago.

Hailstones and Hailstorms

RICHARD J. ROTH, CROP-HAIL INSURANCE ACTUARIAL ASSOCIATION

RAIN-BEARING CLOUDS are a welcome sight to farmers whose crops are in need of moisture. Too frequently, however, the pleasant prospect of life-giving water vanishes when a deluge of solid ice balls hurtles down to ravage the tender, growing plants. Though most people do not have their year's income thus threatened by a hailstorm, they have at some time witnessed the awesome spectacle of falling hailstones.

Close examination of a typical hailstone reveals that it is composed of successive layers of ice, clear layers alternating with snowy, cloudy ones. Not all hailstones are spherical. They have been found shaped like disks, spheroids, pears, giant snow crystals. Some are quite irregular without any seeming design. Most irregularly shaped stones are probably the result of shattering of spherical ones by external or internal forces, or of fusing together during their fall to the ground.

The diameter of an average stone will be somewhere between one quarter and three quarters of an inch, and the average size of a stone when it reaches the ground may be taken as half an inch in diameter. But much larger stones have fallen. The largest authentically recorded in the United States fell during a storm at Potter, Nebraska, on July 6, 1928. One stone measured 17 inches in circumference, almost 5½ inches in diameter, and weighed 1½ pounds. These stones, which were as large as or larger than grapefruit, fell from 10 to 15 feet apart and completely buried themselves where they struck soft or plowed ground. They were not made by fusion, but were individual stones with the typical concentric layers of ice formed around a single center.

There have been a number of cases record-

The enormous size of the hailstones which fell on Columbia, South Carolina, on April 27, 1950 (see front cover), is evident by their comparison with the ruler shown here. Photo by the Munn-Teal Studio, Columbia.

ed of hailstones as large as baseballs, approximately three inches in diameter, and many where the diameter of the stones has been one to two inches. In general, the probability is small of experiencing a hailstorm in which the stones are larger than two inches.

Regardless of the size or shape of the hailstone, it is a product of violent atmospheric convection attending a thunderstorm. As such, hail occurs when the temperatures at the surface of the earth are above freezing, and mostly considerably above freezing. The Thunderstorm Project (a joint investigation of the Air Force, Navy, National Advisory Committee for Aeronautics, and the Weather Bureau) has found that a thunderstorm is an area of convective activity made up of thunderstorm cells. Each cell has a life cycle during which the cumulus cloud develops into a cumulonimbus or thundercloud, precipitates rain and possibly hail, and then dissipates. In one storm, one cell may be in the cumulus stage while another is in the mature stage, and a third may be dissipating. There is a tendency for successive cells to reach greater heights as a well-developed thunderstorm area moves across the country.

Opinions differ as to whether every thunderstorm cell contains hail. Certainly hail does not reach the ground in a majority of cells, and in Thunderstorm Project flights through the cells no hail was experienced in most cases. Hail seems to be associated with only those cells having higher than average updraft velocities, in excess of 35 m.p.h. Probably the season of the year and the geographical location have much to do with the chance of encountering hail in a flight through a thunderstorm.

Hail paths on the ground average from one to two miles wide, but they are not continuous. It used to be thought that a hailstorm precipitates hail for a while, then lifts, only to precipitate more hail at a later time. Now we see that what really happens is that one of the cells matures, precipitates hail, then dissipates. Later another cell matures and produces hail at a different location.

The exact method of hail formation in a thunderstorm is not definitely known. An older theory maintains that a nucleus of frozen water is subject to a series of updrafts and downdrafts, which transport the stone from the freezing region of the cloud to the warmer regions below; there an additional coating of water is added, and then the stone is carried again up into the freezing region. This, the theory contends, is the explanation of the concentric layers of clear and opaque ice. When the stone grows to a size which cannot be supported by the updrafts, it falls to earth.

A newer theory postulates that the frozen nucleus starts to fall and successively encounters supercooled water droplets and snowflakes. There is only one descent, and the amount that the stone grows as it falls depends on how many droplets and flakes it encounters.

The height at which the temperature within

the cloud drops below freezing is, of course, of great interest, as most of the growth of the stone is assumed to occur above this level. In summer in the central United States, the freezing level is generally in the neighborhood of 13,000 to 14,000 feet above sea level.

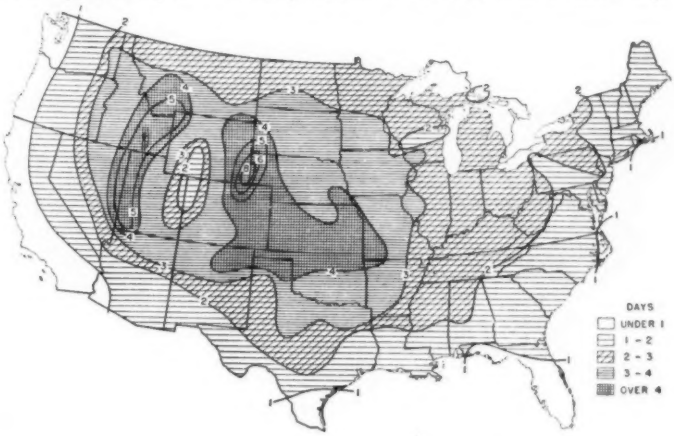
The Weather Bureau for a great number of years has collected data on the number of days with hail at stations throughout the United States. These records, considered with statistics of hail insurance on growing crops, clearly indicate that the area of maximum hail fall in the United States occurs in northern Texas, western Oklahoma, western Kansas, western Nebraska, eastern Colorado, and eastern Wyoming. Areas of light hail fall comprise locations at fairly low altitude and land adjacent to the oceans. An exception to this, according to Weather Bureau records, is found in two areas of secondary maximum of hail fall on the Pacific Coast in northern California and in southern Washington. There, however, hail is a winter phenomenon, and many of the observations of hail might have been classified as snow pellets. The crop-hail insurance statistics do not show this secondary maximum, and would not be expected to, since the crop season does not occur in the winter months.

There seems to be a close relationship between the altitude of the land above sea level and the amount of hail; the higher the altitude, the greater the hail fall. The reasons for this are not clear, a partial explanation being that the distance from the freezing level to the ground is less in high-altitude regions, and consequently, the hail has less opportunity to melt.

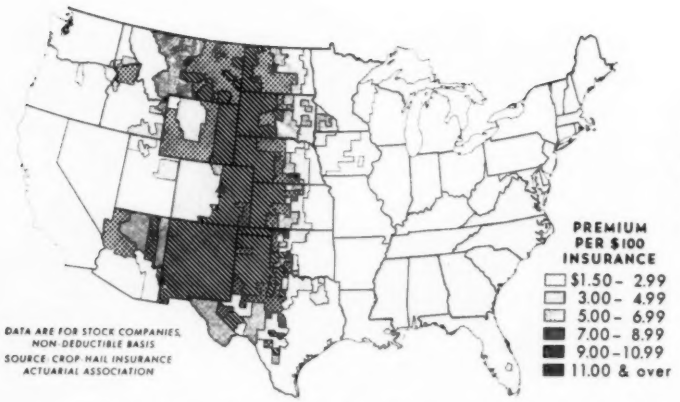
Some preliminary investigations have revealed a relationship between slope of land and hail fall. If a hailstorm is moving downslope, it seems to produce more hail than if it is moving upslope. This is in addition to the altitude effect.

Since thunderstorms are the producers of hail, it would seem that the regions of maximum thunderstorm activity would also be the regions of maximum hail activity. This is not so. In the United States, the area with the greatest number of thunderstorms is Florida, which is also the area with the least number of hailstorms. This indicates that in Florida a great proportion of the thunderstorms do not precipitate hail, while in the Great Plains a high percentage do. For example, from 1904 to 1943, Tampa had 3,681 days with thunderstorms, but only 21 days with hail. Dodge City, Kansas, in the same period, had only 1,778 days with thunderstorms, but 175 days with hail. Consequently, Tampa had one day with hail for each 175 days of thunderstorms; Dodge City had one day with hail for each 10 days of thunderstorms.

Hailstorms are at a maximum in the spring and early summer. Dodge City, for example, had 127 of its 175 days with hail, or 73 per cent of the total, in the four months from March through June. The area of maximum hail fall tends to follow the apparent path of the sun northward. In April, the area of maximum hail frequency is centered in northern Texas and western Oklahoma; in June it is located in western Kansas, western Nebraska, eastern Colorado, and eastern Wy-



The average annual number of days with hail, based on 200 first-order USWB stations, from data for the period 1899 to 1938.



Hail insurance rates for small grains in 1950, according to the Bureau of Agricultural Economics, U. S. Department of Agriculture.

oming; and in July, in western Nebraska, southwestern South Dakota, and eastern Wyoming. Unfortunately for agriculture, the season of maximum hail activity coincides with the growing period of many important crops. This increases the probability of hail damage to growing crops and is responsible for vast annual losses.

Some foreign countries have experimented with methods of hail prevention by attempting to modify or change hail-producing clouds. These early attempts included the use of hail cannon and rockets to shoot explosive charges into thunderclouds. It was reasoned that this would disturb the circulation within the cloud and prevent the formation of hail. Also, elaborate devices on the ground, in the nature of large lightning rods, were supposed to affect the electrical charge of the thundercloud in such a manner as to prevent the forming of hailstones. Meteorologists have not considered the results of these experiments conclusive.

Very recently, attempts at hail suppression have been made in the United States by cloud seeding with silver-iodide crystals. The idea behind these attempts was that if the number of condensation nuclei are greatly increased within a thundercloud, the resulting hailstones will be very numerous and small in size, probably melting before they reach the ground. There may also be the possibility of "overseeding" the cloud and preventing precipitation altogether. These experimental tests have occurred so very recently that data concerning them are unavailable for critical study, and their potentialities are not known at present.

There is, to date, no proven method of complete hail suppression. But crop-hail insurance provides the needed protection for agricultural interests; similar coverage is offered to other property owners by appropriate insurance.

HEAVIEST RAINS

Cherrapunji, in India's Assam province, holds all world records for continual heavy rainfall over periods ranging from four days to two years, according to a recent compilation released by the National Geographic Society. Through 1860 and 1861, a total of 133 feet nine inches of rain fell there, more than 30 feet in July, 1861, alone. In 12 months the total fall was 86.75 feet, more than the average depth of the Mississippi River at New Orleans.

On four June days of 1876, Cherrapunji was drowned under 101.84 inches, and in 1931 a week of rain brought down 131.15 inches.

The one-day record for rainfall is held by Baguio, a mountain city north of Manila in the Philippines: 45.99 inches. In the same storm in July, 1911, a total of 87.01 inches, more than seven feet, fell in three days and 15 hours. The two-day record was set in July, 1913, at Funkiko, Formosa, with 65.79 inches. Silver Hill plantation in Jamaica was drenched in November, 1909, by 57.5 inches in two days, 122.5 inches in six days, and 135 inches in eight days.

Bassetere, St. Kitts, in the West Indies, received 23 inches of rain in four hours, on January 12, 1880.

Activities of the Geophysics Research Division, AFCRC

H. E. LANDSBERG, DIRECTOR, GEOPHYSICS RESEARCH DIVISION
AIR FORCE CAMBRIDGE RESEARCH CENTER

THE Geophysics Research Division, Air Force Cambridge Research Center, Air Research and Development Command, has now been in existence for a little over five years. During that time it has grown from a complement of six to nearly 300 persons. Its prime purpose is to fill the geophysical research needs of the operating commands of the United States Air Force. Naturally, these needs call mainly for more knowledge of the atmosphere, and hence our major efforts are concentrated on acquiring new meteorological knowledge. There are collateral interests in some of the other fields of geophysics concerned with interactions between the atmosphere and the solid earth and the water on the earth.

The scientific program of the division is geared toward long-range objectives, the ultimate aim being to enable accurate forecasting of all atmospheric events at all levels. This includes not only the conventional synoptic weather problems but also elements less in the focus of meteorological attention. Among these are the behavior of the ionosphere, of the optical and electrical parameters at all levels, and the composition of the atmosphere and its solid and liquid suspensions. The last-mentioned item includes, of course, the whole field of cloud physics. In this, as well as in other areas, the research efforts are directed toward fundamental understanding of the processes involved. It is evident that only if we really determine cause-and-effect relationships will quantitative atmospheric prediction be possible. We are under no illusions regarding the immediate feasibility of this, but we are convinced that the "rough and ready" approach will give only marginal improvement over present methods. This does not mean contempt for short-term practical solutions to meteorological problems — in fact, the Geophysics Research Division has a full share of projects with limited objectives where answers are wanted quickly and where

In the Terrestrial Sciences Laboratory, one of the projects is the determination of soil trafficability. When released from an airplane, the drop penetrometer will indicate the consistency of the ground surface before a landing and surface traffic are attempted. In this picture, the penetrometer will be driven downward under pressure into a soil sample. The depth of penetration is measured, the intensity of impact determined and compared with the bearing capacity of the soil. Such laboratory tests and additional field tests provide data necessary for accurate calibration of the drop penetrometer.

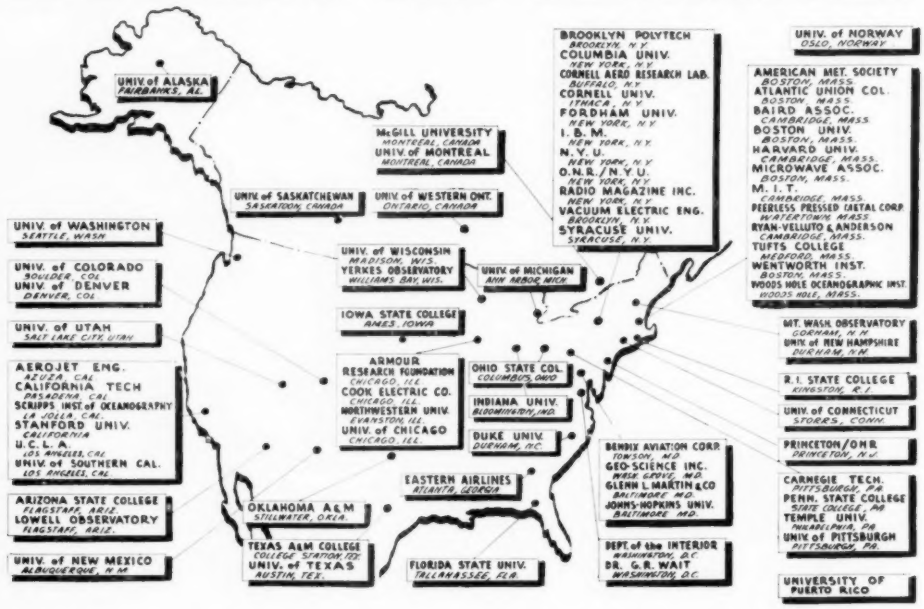
even a limited solution is better than none.

There is no space to list all the many interesting projects carried on within or sponsored by the division. In meteorology proper, we are jointly engaged with other groups in studies of the general circulation in the atmosphere and are pursuing special studies directed, not without success, toward methods of numerical forecasting. Intimately related to this are two extensive field projects. One deals with mountain-induced waves and is being conducted with gliders operating in the High Sierras. The other is the study of upper winds by constant-level balloons, carried on under the nickname of "Moby Dick" (WEATHERWISE, December, 1951, page 123).

Improvement of short-range and long-range weather forecasts by objective and contingency methods are part of the program. Turbulence and diffusion in the atmosphere belong to the "tough nuts" that we are trying to crack by a closely co-ordinated theoretical and observational attack. In the already mentioned field of cloud physics we are interested in the physicochemical problem of nuclei and aerosols. Again, a combined laboratory and field approach is used to tackle such problems. The field work includes the study of clouds by microwave techniques.

In the foregoing areas our aim is not much different from that of other scientists and agencies in the field. Our work is closely coordinated with them, so that a real, unified, scientific attack on the problems can be said to exist. The same co-ordinated approach holds for our work in exploring the high atmosphere above the levels readily accessible to balloons. We are trying to exploit to the fullest the opportunities now afforded by rockets. Here we are at the threshold of many exciting discoveries. The state of the art is comparable to that existing for the lower levels prior to the discovery of the stratosphere nearly five decades ago. It is a path fraught with disappointments because of the unreliability of the vehicles and the shortness of flight time within which to gather information. Yet we have high hopes of accumulating valuable data not only on the normal elements of density, pressure, and tempera-

LOCATION of GRD CONTRACTORS



Some of the centers of research co-operating with the Air Force in the activities of its Geophysics Research Division are shown here.

ture, but on radiative processes in the atmosphere including better determinations of the solar constant.

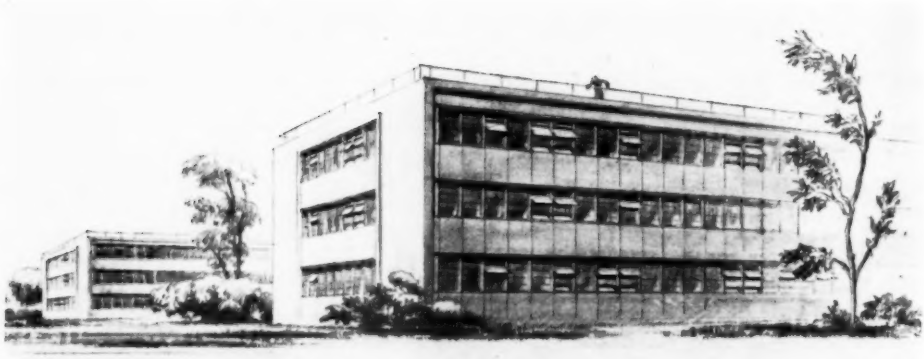
Simultaneously, we are trying to develop indirect acoustical and optical probing techniques for these same goals to correlate with the rocket data, since the latter can presently, at best, give us only sporadic information. Beyond the present rocket ceiling, these same indirect techniques are being exploited for data on the layers where the atmosphere gradually merges with interplanetary space.

It is here that extraterrestrial influences most manifestly affect the atmosphere and that energy transactions of uncertain but by no means negligible magnitude take place. Many paths of these problems lead to the sun, and observations of solar activity are a logical keystone to the effort. In the sun should be found the answers to many of the questions that puzzle us at present, whether they concern long-term climatic changes, shifts in the large-scale circulation of the lower atmosphere, fleeting fluctuations of the ionosphere and of the earth's magnetic field, or auroral displays.

Among our other interests are microseisms related to weather events, hydrometeorological influences on forecasts of soil trafficability, and wind stress influences on the arctic ice pack.

Our workload is divided among five laboratories. Their titles are barely descriptive of their functions, but the parenthetical notes may serve to amplify them: Atmospheric Analysis Laboratory (synoptic and dynamic meteorology); Atmospheric Physics Laboratory (atmospheric composition and chemistry, cloud physics, atmospheric optics and electricity); Upper Atmosphere Laboratory (rocket sounding in all its ramifications); Ionospheric Laboratory (electromagnetic wave sounding, aurorae, physics of the inaccessible layers); Terrestrial Sciences Laboratory (soil trafficability, microseisms, elastic waves in air). A research library of some 100,000 volumes is one of our proudest possessions and one of the indispensable tools for our in-house research efforts. The solar studies are carried on at the Upper Air Research Observatory, Sacramento Peak, New Mexico — an off-base facility, where the finest coronagraphic equipment is being assembled and studies on solar noise and flares are under

Members of the Geophysics Research Division here conduct final instrument checks before the assembling and launching of a V-2 rocket. This is an Upper Atmosphere project. U. S. Air Force official photograph. Holloman Air Force Base.



An architect's drawing of the buildings being constructed at Bedford, Massachusetts, to be the new home of the Air Force Cambridge Research Center, of which the Geophysics Research Division is one part. Other major sections are the Electronic Research Division and the Atomic Warfare Division.

way, which should yield important data.

As part of the Air Force Cambridge Research Center, we are at present housed in an old wool warehouse at 415 Summer Street in South Boston. The Center is hopeful that under a congressionally authorized program all of its research facilities may soon be housed in adequate well-equipped laboratory buildings to be erected in the area of Hanscom Air Force Base, Bedford, Massachusetts, in the suburbs of Boston.

For all our work we have the finest cooperation from many contractors all over the United States and Canada. A glance at the chart on page 56 shows that many universities, observatories, and commercial firms are supporting us in our endeavor to advance the frontiers of meteorology. We are also pleased to acknowledge the help given to us by the American Meteorological Society. Permanent monuments to this co-operation are the *Compendium of Meteorology* (reviewed in WEATHERWISE, April, 1952), and the publication of *Meteorological Abstracts and Bibliography*, now in its third year. With this support from the whole profession of meteorology and many scientists in the adjacent fields of geophysics, physics, chemistry, and mathematics, we have full confidence that we shall not fail in our mission to apply the best available knowledge to Air Force operations and the common defense in general.

VOLCANOES AND WORLD CLIMATE

Above is the title of an article in *Scientific American* magazine for April, 1952, by Harry Wexler, chief of the Science Services Division of the U. S. Weather Bureau. He proposes that "explosions of volcanoes may play an important part in shaping long-term variations in the world's climate."

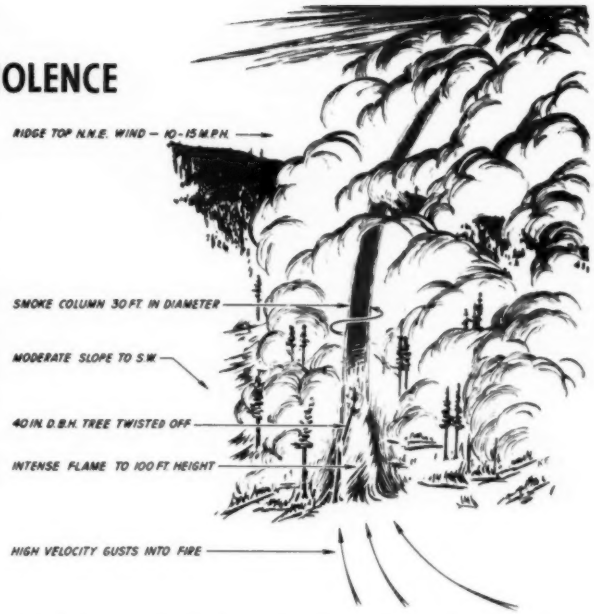
Dr. Wexler points out that this is not a new theory, but that there are new reasons now for reviving and reconsidering it. A single volcanic explosion can block as much as 20 per cent of the incoming solar radiation, and may substantially reduce the heat received at the earth's surface for as long as three years. Volcanic ash may furnish nuclei for cloud formation and therefore cause additional shielding of sunlight.

A long series of explosions, such as those of Krakatoa, Tarawera, Bandai San, Bogoslof, and Awoe, extending from 1883 to 1892, can bring on severe winters; perhaps a really long and violent series can give rise to an ice age. The Krakatoa explosion in the Dutch East Indies on August 27, 1883, threw some 13 cubic miles of rock, dust, and ash into the air. High in the atmosphere, this dust and ash affected atmospheric transmission for three years at such distant places as southern France.

A FIRE-WHIRLWIND OF TORNADIC VIOLENCE

HOWARD E. GRAHAM

FIRE WEATHER SERVICE
USWB, PORTLAND, OREGON


RIDGE TOP N.N.E. WIND — 10-15 M.P.H.
SMOKE COLUMN 30 FT. IN DIAMETER
MODERATE SLOPE TO S.W.
40 IN. D.B.H. TREE TWISTED OFF
INTENSE FLAME TO 100 FT. HEIGHT
HIGH VELOCITY GUSTS INTO FIRE

A diagram of the fire-whirlwind observed at the Vincent Creek fire, which shows the tornadic violence of this phenomenon. Such a tornado in a forest fire may form and disappear, only to occur again in the same location as long as the fire situation and the meteorological conditions remain favorable. Drawing by a draftsman of the Pacific Northwest Forest and Range Experiment Station.

WHIRLWINDS have been reported from time to time as occurring within various types of fires, but accounts of sufficient detail to give the reader a definite idea of what the reporter actually saw are rare. Since the fire-whirlwind is a phenomenon of considerable importance to fire fighters, I will attempt to describe one observed by Robert S. Stevens, Forester, Oregon State Board of Forestry, and myself at 2 p.m., August 23, 1951, on the Vincent Creek fire in southwest Oregon.

From our vantage point about 200 yards away it was evident that violent whirling surface winds existed near the fire over a diameter of some 100 to 200 feet. In the middle of this circulation was a dark tornado-like tube extending upward, whose top was obscured by drift smoke above approximately 1,000 feet. The winds in this tube were so extreme that a green Douglas-fir tree, which at breast height was about 40 inches in diameter, was quickly twisted and broken off about 20 feet above the ground. Near the whirlwind the fire flames leaped several times higher than those in surrounding areas. A large treetop burst into flame like the flash of a powder keg when the whirl passed by. Within the tube, gases and debris were moving upward at a high velocity. The whirling column remained nearly stationary during its activity, moving little more than 50 yards; had that not been the case, extremely rapid fire spread might have resulted. The whirlwind rapidly disappeared and as rapidly re-formed a moment later, repeating this procedure at least three times during a 10-minute interval.

The general fire was on a 50-per-cent south-southwest slope. The trees were widely spaced with fuels consisting of low brush, weeds, snags and down logs typical of an old burn in this region. The fire front was moving steadily along the contours and extended up the entire slope, about half a mile from top to bottom. Flames along the front were about five feet high, and shorter flames persisted to a distance of about 50 feet behind. A slight spur ridge projected from the slope so that updrafts were moving from both the south and the southwest into the area of the whirlwind. The fire-whirlwind developed a few feet behind the fire front about 150 yards from the summit of the main ridge and on the spur ridge.

The meteorological condition of the atmosphere was one of conditional instability. Overturning of the air in the lower layers could readily occur if the surface were heated sufficiently. No cumulus clouds were to be

(Continued on page 62)

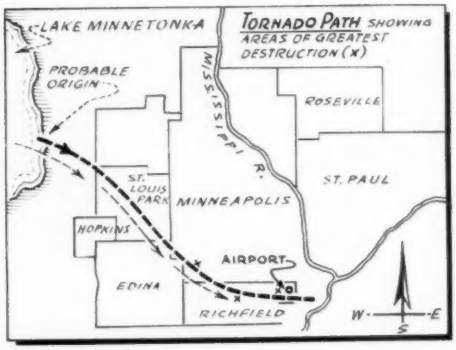
The Hennepin County Tornado of

M. R. HOVDE, SECTION DIRECTOR, USWB, MINNEAPOLI

AN UNUSUALLY VIOLENT TORNADO struck parts of Hennepin County, Minnesota, during the evening hours of July 20, 1951. It was the most destructive twister to hit in the Gopher State since 1874, leaving a toll of five persons dead and over six million dollars damage. But this particular storm was more noteworthy in meteorological annals in another way, being one of the few cyclonic funnels to pass almost directly over a first-class weather station, so that approximate measurements of the terrific fluctuations of the weather elements could be made.

The funnel apparently originated in the Lake Minnetonka area about 10 miles west of downtown Minneapolis. The first destruction was reported there about 9:00 p.m. Shortly afterwards, three houses near 59th Street and Logan Avenue in south Minneapolis were demolished, and several others in the Richfield area were hit by the skipping path of the twister. The next point of contact appears to have been the Wold-Chamberlain Airport where the greatest destruction took place. In all, the path of the tornado was about 18 miles long, from northwest to southeast at the start, but from west to east at the end.

At the airport, hangars, barracks, and auxiliary buildings were either demolished or severely damaged. The greatest havoc, of course, was among aircraft both in hangars and parked on the field; in all, 63 airplanes of all classes were destroyed and about 37 others damaged.



The Hennepin County tornado followed a path from near Lake Minnetonka across the southern part of the city of Minneapolis, causing particularly heavy damage in south Minneapolis, Richfield, and at the Wold-Chamberlain Airport.

Three dwellings in a row were completely demolished a Minneapolis near 59th Street and Logan Avenue duri

Throughout the area there was great disruption to power and communication lines, and traffic was practically brought to a standstill by more than 600 trees felled by the tornadic winds. A large tent in south Minneapolis, where hundreds of people were attending a revival meeting, was torn from its moorings by the wind, and six persons were injured there. A streetcar was overturned and tossed into a ditch, reminiscent of the memorable twister of May 27, 1931, that hit the crack limited, Empire Builder, at a right angle as the train was speeding along at 60 m.p.h., lifting five coaches from the tracks and derailing seven others.

The meteorological climax of the storm came at 9:26 p.m., when the barograph at the Weather Bureau Airport Station at Wold-

demolished and scattered over the neighborhood in south Avenue during the severe tornado of last July 20th.

nado of July 20, 1951

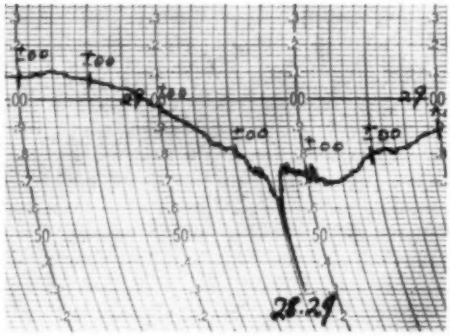
MINNEAPOLIS, MINNESOTA

Chamberlain Airport registered an abrupt fall of 0.34 inch to a low of 28.29 inches (station pressure) and an almost simultaneous rapid rise. The wind, which had suddenly increased at 9:15 p.m. to gale force, reached hurricane force at 9:26, when the anemometer recorded 84 m.p.h. from the west for a sustained five-minute period and an extreme gust of 92 m.p.h. from the west at 9:27, establishing new wind records for Minneapolis. The hourly precipitation had to be estimated, because the tipping bucket was blown away, and the triple register failed at 9:33 when electric power lines collapsed.

A new record for the greatest 24-hour rainfall at nearby Maple Plain was established, with 8.50 inches falling between 7:15 p.m. and about 1:00 a.m. on the 21st. Excessively heavy rains were also reported from Mound, Long Lake, Robbinsdale, Crystal, and Golden Valley. The Empire Builder again was involved, as washouts held it all night in the vicinity of Maple Plain. Much damage was caused to low-lying houses by flood waters, and garden crops were ruined by the deluge.

The meteorological aspects of the storm have been carefully analyzed and are here described by Meredith Wingert, of the Weather Bureau Forecasting Center at Wold-Chamberlain Field.

"By 2000C thunderstorms were common in a band about 100 miles wide north of the warm front in Minnesota, which included the Minneapolis and St. Paul area. Nothing unusual was noted in the sky condition until about 1900C, when a black cloud, stratiform in appearance, was observed directly overhead, centered in a large break in the predominating alto deck of clouds. Within five to 10 minutes this cloud had mushroomed into a cumulonimbus. Thunder began shortly after 1900C, accompanied by light to moderate showers between 2000 and 2100C, with continuous bright lightning over the entire sky. At 2100C reports of heavy rain and strong winds were received by the Weather Bureau Airport Station, Minneapolis, from points 10 miles north of the station to 25 miles northwest. The station pressure began to fall rapidly at 2100C, but the wind remained southeast to east at 20-30 miles per hour. At 2120C the wind began to increase from these directions to 20-40 miles per hour, with gusts to 60 miles per hour, and the rain became



This photostat of the barograph tracing from the Minneapolis Weather Bureau shows the extremely sharp fall and rise registered at the height of the storm as it passed the Airport Station.

heavy. Between 2126 and 2130C the wind shifted to southwest 80 miles per hour, with the needle of the gust indicator striking the end of the gage at 100 miles per hour with some force, indicating that gusts exceeded that limit appreciably. This velocity continued until the instrument failed at 2133C, but the direction became extremely variable, the vane making complete revolutions at least twice just before failure.

"Radiosonde data from St. Cloud, Minnesota, over the 60-hour period preceding the storm, disclosed rather uniform warm air advection below 300 millibars (30,000 feet), with the area of greatest temperature increase at 850 mb (5,000 feet), and cold air advection above 300 millibars, with the greatest net fall in temperature at 150 millibars (40,000 feet). With the surface data at Minneapolis at 1830C on the 20th it was determined that conditional instability existed to approximately 45,000 feet. The 1500C pilot balloon sounding at St. Cloud on the 20th only reached 16,000 feet with wind southwest 50 miles per hour at 5,000 feet, southwest 30 miles per hour at 10,000, and west 40 miles per hour at 16,000 feet. However, the 0900C sounding reached 35,000 feet, showing west-northwest 41 miles per hour at 20,000, northwest 56 miles per hour at 25,000, northwest 62 miles per hour at 30,000, and northwest 73 miles per hour at 35,000 feet."

A FIRE-WHIRLWIND OF TORNADIC VIOLENCE

(Continued from page 59)

seen. Winds at ridge top were north-northeast from 10 to 15 m.p.h. Above the ridge-top level, winds were from north-northwest to north-northeast and ranged from eight to 16 m.p.h. up to 10,000 feet. The relative humidity was 46 per cent and the temperature 67°, neither being unusual.

Much has been written on various types of whirlwinds and their causes, yet much is still to be learned. Meteorologists know that these whirlwinds are present only where the atmosphere is in a particular condition of unstable equilibrium: where the temperature decreases so rapidly with height that the warmer air below, being lighter than the cooler air above it, tends to rise and the cooler air aloft tends to sink. The result is intense vertical currents throughout the unstable layer.

In this case, the heat from the fire caused the unstable conditions—an entirely normal situation over a large fire. Since these violent fire-whirlwinds are infrequent, there must be conditions other than heating to cause their formation. Perhaps the answer lies in the interplay of wind currents and topography. In the case under discussion, consider the position of the whirl near the top of a sunlit south-southwest slope where it was fed by upslope drafts from the south and southwest in the surface layers. Above the level of the ridge, the rising currents from the fire were played upon by the prevailing gentle to moderate north-northeasterly wind. There were two opposing air currents with a column of rapidly rising gases between them, an ideal condition for the formation of mechanically induced eddy currents, which, once started, might be sustained by the energy of the rising hot gases. This theory is substantiated by the repeated reappearance of the fire-whirlwind in the same spot. As the leading edge of the main fire progressed, the fuels in the area of the whirl were consumed and the volume and heat of the ascending gases apparently became insufficient to support the whirlwind. As the fire moved on to new fuel and new topographic features, no further disturbance was noted.

From this analysis, it would seem likely that there are certain ideal combinations of conditions under which this type of fire-whirlwind of extreme violence might occur. The necessary factors seem to be for the fire to be on the lee slope sheltered from the prevailing ridge-top winds, a moderate or stronger wind at the ridge top, and strong converging surface updraft currents along the burning or sunheated slopes.

It would be desirable to have the necessary combination of conditions more positively identified, so that fire fighters could learn to anticipate at least this one type of blow-up fire behavior. Additional detailed reports of similar phenomena would contribute to the understanding of their causes and their effects. These accounts should attempt to describe the topography, surface wind, ridge-top wind, fire intensity, cloud types, smoke-column characteristics, and the intensity of the fire-whirlwind.

FLOODS AND TORNADOES MARK EARLY SPRING

MARCH, the first month of the spring season, again found the country split into two distinct climatic provinces, as has happened so frequently in recent months. In the western two thirds of the country it was cold and stormy, while it was relatively mild in the East.

Below-normal temperatures were general west of the Chicago-Nashville-Pensacola axis, and the departures from normal exceeded eight degrees over a considerable area in the Rocky Mountains and the plateau states. Large areas of the West received from 150 to 200 per cent of normal precipitation and more. Snowfall continued over the mountain areas, and by the end of April the total 1951-1952 fall had reached 777.8 inches at Soda Springs, California. At Norden, California, the pack measured 314 inches on March 20th, exceeding the long-standing record of 1907 by nine inches.

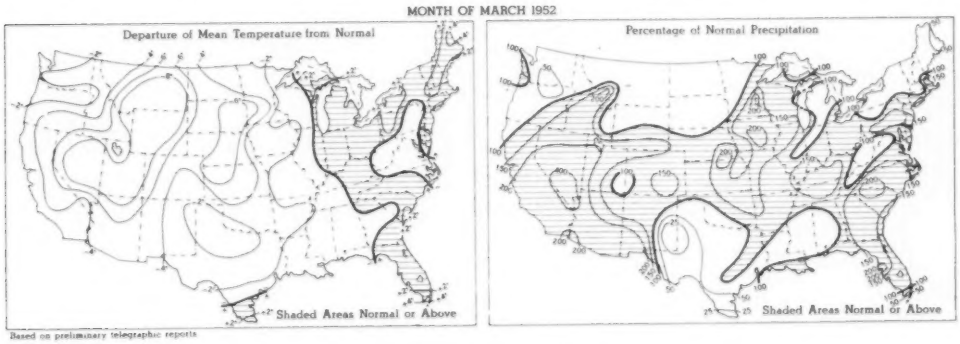
In the Ohio Valley and along the Atlantic seaboard, spring progressed at a normal rate, with most areas having average temperatures two degrees above normal, except for the interior of the Middle Atlantic states, where the mercury averaged just about normal. Precipitation along the coast was heavy, but in New York and New England fire-weather conditions began to develop as the month drew to a close.

An explanation of the contrasting weather patterns is readily found in the upper-air circulation. The dominant feature was a large north-south ridge of high pressure that extended from south of Alaska through the eastern Pacific Ocean, along the longitude meridian 145° west. Down the eastern side of the ridge there was maintained a strong flow of northwesterly winds, bringing cold, polar air from Alaska and northern Canada into a long trough that was oriented northeast to southwest, from central Quebec to the upper Great Lakes and on eventually to Lower California. This trough was the scene of all major storm activity, and a series of low pressure areas moved from the Pacific Ocean across the country to the Atlantic Ocean.

The first storm of the series took this course between February 29th and March 5th. It was noteworthy in bringing precipitation to all parts of the country: on March 2nd, rainfall was reported in a solid band from San Diego to Cape Hatteras. Storm No. 2 looped through the Southwest, starting on the 6th, deepened to a minimum of 28.94 inches in Indiana, and passed off New England on March 12th. The third storm moved down from the Northwest and dropped to a pressure of 28 95 inches over Kansas, causing winds up to 80 m.p.h. in gusts, with near blizzard conditions in the upper plains and duststorms in the lower plains. Storm No. 4 was a mild affair, in transit from the 14th to the 20th.

The fifth storm of this series was the major disturbance of the season. It appeared as a severe depression (28.88 inches) off the British Columbia coast on March 17th, following a steady course southeastward to western Texas, where it joined a trough that ran from Arizona northeastward to Missouri. By early on March 21st, a distinct center had formed, and this was located the next day over Illinois and Iowa, pressure 29.50 inches. The storm then drifted directly northward over the upper Great Lakes. This was a remarkable storm, not so much for its barometric depth but for the energy of the contrasting air masses involved. It brought more duststorms to the arid Southwest, and produced the worst blizzard conditions of the winter on the Great Plains. There were wind gusts up to 70 m.p.h. and sustained 50-m.p.h. winds for 36 hours in Nebraska, heavy snowfalls up to 15 inches in the upper plains, and the most destructive tornadoes in recent years in the lower Mississippi Valley.

Arkansas Tornadoes. "Miles and miles of toothpicks" was the description of one newspaperman who flew over the scene of the series


MONTH OF MARCH 1952
Departure of Mean Temperature from Normal
Shaded Areas Normal or Above
Percentage of Normal Precipitation
Shaded Areas Normal or Above
Based on preliminary telegraphic reports

U. S. Weather Bureau charts for temperature and precipitation, March, 1952.

of tornadoes that swept the state of Arkansas on the afternoon and evening of March 21st. The first outbreak occurred at Dierks, in the southwestern corner of the state, at about 3:00 p.m. CST. At this time a cold front was oriented northeast and southwest just across the extreme northwest corner of Arkansas, and a squall line apparently formed some 200 miles ahead of the front and moved northeastward. The next outbreak came about an hour later just to the west of Little Rock, and from then on there appeared to be three tracks, with tornadoes skipping along in parallel columns. They finally passed out of the northeast corner of Arkansas about 8:00 p.m. Twisters were reported in Tennessee, Missouri, and Kentucky that evening, with the last taking place about midnight. The foregoing information was supplied by Walter C. Hickmon, of the Little Rock Weather Bureau.

The greatest damage took place in White County, about 50 miles northeast of Little Rock, in the towns of Judsonia, Bald Knob, and Searcy. Judsonia, with a population of 1,011, is the center of the strawberry-raising region; there only one building, the Methodist church, was left undamaged. The scene was described as resembling a battlefield, and the highways were jammed with refugees. The latest estimate for Arkansas alone listed 111 killed, 788 injured, 679 homes destroyed and 1,219 damaged. The death toll in all states for two days of tornadoes was 233, and the damage near 50 million dollars. This was the fifth worst tornado disaster in our nation's history; the greatest single tornado catastrophe was that of March 18, 1925, in which some 700 lives were lost in Missouri, Illinois, and Indiana.

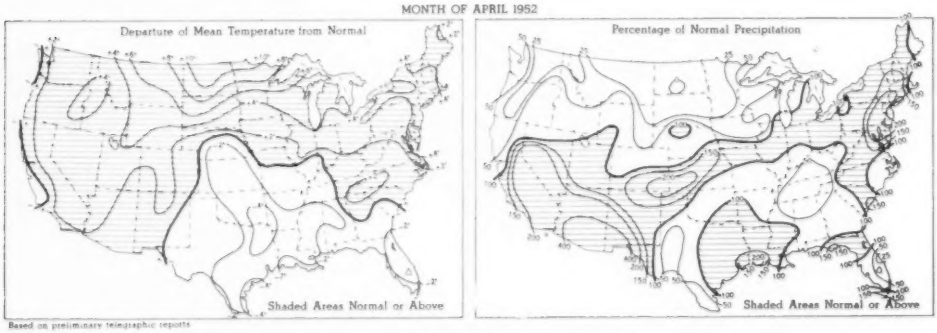
The March, 1952, tornado outbreak occurred in a typical meteorological situation. A very warm air mass occupied the lower Mississippi Valley on the 20th and 21st. The 65° dewpoint line extended just to the north of Memphis, indicating the presence of air potentially very unstable. An upper-air sounding at Little Rock showed that the moist layer extended to about 6,000 feet and then dropped off rapidly in a drier layer. Wind flow was strong from the southwest at all levels, but increased with height to give a vertical wind shear. As the squall line moved through this unstable air mass, it triggered the series of twisters.

One of the evening funnels passed right over the airport at Dyersburg, Tennessee, from 8:31 to 8:38 p.m. CST, on a course from south-southwest to north-northeast. The CAA observer on duty noted the time and saw his microbarograph dip from a slowly falling 29.20 inches into an abrupt fall to 28.52 inches, followed by an equally sudden rise. The center of the funnel passed just 123 feet south of the barograph, and the width of the path of destruction at the airport was only 775 feet.

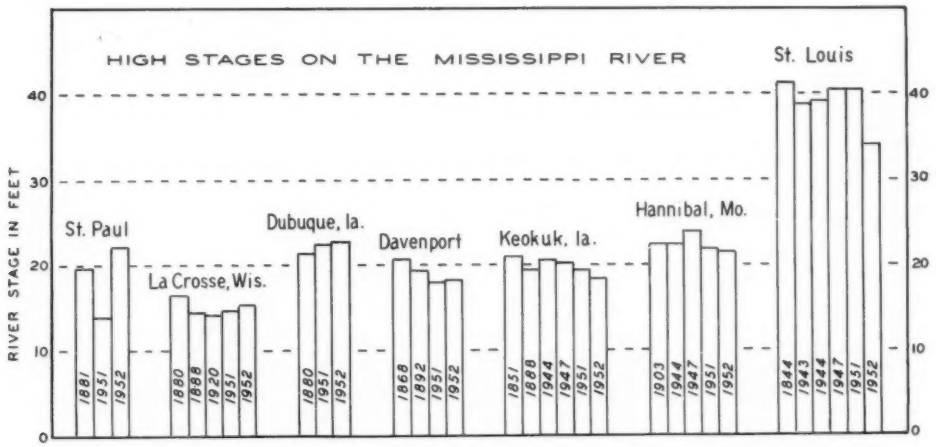
The great March 20-22 storm established an air-flow pattern that continued for almost a week. A circular low aloft with a closed cyclonic circulation established itself over the upper Middle West and brought an onrush of polar air from Canada to delay further the advent of spring weather. Not until the 28th did the Pacific-ridge central-trough regime show signs of breaking down. Then mild Pacific air was introduced into the continent, and a transformation to May-like temperatures took place in all the northern parts of the country. Dodge City, Kansas, had a reading of 81°, North Platte, Nebraska, 74°, and Grand Rapids, Michigan, 70°.

Like its predecessor, the month of April divided climatologically into two distinct periods. The backward spring conditions in the farming areas of the West continued, with temperature during the second week of April nine degrees below the seasonal average. At Tomahawk, Wisconsin, the mercury dropped to —4° on the 11th, and snow fell to a depth of six inches as far south as lower Michigan on April 5-6.

The circulation pattern of early April resembled that of March, although neither the Pacific ridge nor the trough in the Middle West were as well developed as they were in the stormy days of the previous month. On the 15th and 16th, the upper-air flow shifted quickly and decisively. High index conditions took a


MONTH OF APRIL 1952
Departure of Mean Temperature from Normal
Shaded Areas Normal or Above
Based on preliminary telegraphic reports
Percentage of Normal Precipitation
Shaded Areas Normal or Above

U. S. Weather Bureau charts for temperature and precipitation, April, 1952.



This diagram shows the recorded height in feet for various record floods in cities along the Mississippi River. The highest record flood stage shown, and also the earliest, that of 1844 in St. Louis, at 41.4 feet, has not been exceeded to date.

firm hold, and the flow of polar air into the United States was stopped. The track of low pressure centers now was across central and northern Canada, with westerly and southwesterly winds dominating the flow pattern to the south. Temperatures in the upper plains soared to summer readings after the 15th: Glasgow, Montana, 87°, and Minot, North Dakota, 85° on the 19th; and a week later the mercury spurted to 93° at Glasgow on the 26th and at International Falls, Minnesota, on the 27th.

Floods on the Missouri. The outstanding feature of the period was the great flood on the upper Missouri River, where flood stages exceeded all existing records at many points from just below Bismarck, North Dakota, to Omaha, Nebraska. The cause of the flood was solely snowmelt, since great accumulations of water were locked in a dense snowcover that rested on frozen ground. Pierre, South Dakota, for instance, on March 18th had a snow depth of 15 inches and a water equivalent of 7.67 inches. During the three winter months, precipitation there had been 460 per cent of normal. These figures were repeated, to a lesser degree, at many other points in the Dakotas and Minnesota. There were also considerable thicknesses of ice locking much water in frozen form over the lakes and rivers of the area. At Pierre, the ice was 20 inches thick, at Bismarck, 27 inches, and at Williston, North Dakota, 32 inches.

Temperatures began to soar above freezing in the Dakotas on March 27th, and the daily maximum continued above freezing thereafter (Pierre had a maximum of 71° on April 7th). The snow melted rapidly, and the breakup of the Missouri River came swiftly. The flood crested at Bismarck at 27.8 feet on April 6th; this was 3.8 feet below the record stage of 1881. But from there southward it was the greatest flood of record, as the heavy snowcover of South Dakota poured its waters into the ice-jammed streams.

The following dates and figures compare the 1952 crests with record floods of the past:

Place	1952	Feet	Record	Year
Mobridge, S.D.	April 9	25.1	19.6	1943
Pierre, S. D.	April 10	24.8	23.0	1881
Sioux City, Iowa	April 14	24.4	22.5	1881
Omaha, Neb.	April 18	30.2	24.7	1881
St. Joseph, Mo.	April 23	27.2	27.2	1881
Kansas City, Mo.	April 24	30.7	38.0	1844
Jefferson City, Mo.	April 27	26.0	34.2	1951

Severe flooding also occurred on the Minnesota-Mississippi rivers system. At the confluence of these two streams that drain much of Minnesota, the stage at St. Paul rose to 22.2 feet, which was 2.5 feet above the highest previous stage in the 1881 flood. Farther down river, the flood was also the greatest in history — Dubuque, Iowa, equaled the crest of 1951, and as far south as Muscatine, Iowa, past records were exceeded. The crest reached St. Louis, Missouri, as predicted on May 1st, but the stage of 33.7 feet was well below the record of 41.4 feet set in 1844.

Floods also plagued the Salt Lake City area in Utah. Record snow accumulation in the Wasatch Mountains melted during the middle days of the month under the influence of high index conditions. Alta, Utah, reported a total snowfall of 600 inches in the past winter, and Brighton, Utah, had 460 inches. The shallow stream beds were unable to handle the deluge, and many streets of Salt Lake City became temporary river beds. A major disruption of the life of the community took place, as many city blocks had to be evacuated.

D. M. L.

FORECASTING THE WEATHER

The Santa Ana

LEO A. SERGIUS, U. S. WEATHER BUREAU
AIRPORT STATION, LOS ANGELES, CALIFORNIA

SOUTHERN CALIFORNIA has a local wind known as the Santa Ana. It is a foehn-type descending wind that blows violently from the northeast and east in particular areas, obscuring the sky with great quantities of dust; clearing skies, rising temperatures, and decreasing humidity are additional distinctive features. It blows across ridges and through the mountain passes of southern California down through the canyons toward the Pacific Ocean. Often the original temperature of the invading air mass is sufficiently cold so the layer of air spilling over the mountains is several thousand feet thick. The movement of this air westward and southward causes severe turbulence in these areas.

The Santa Ana is a strong, gusty surface wind sometimes exceeding 60 miles per hour. In the Santa Ana storm of March 22, 1952, the highest surface winds reported on the hourly airways sequence collection for weather stations at Sandberg and Ontario were northeast 50 m.p.h. with gusts to 68 m.p.h., and northeast 40 m.p.h. with gusts to 60 m.p.h., respectively.

To show the wind flow pattern, to localize the areas of strongest winds, and to display the eddies, Figs. 1 and 2 are presented here. Since the velocity of the wind is a vector, two sets of lines are required, one set for the wind direction (**streamlines,** solid on the charts) and the other for the wind speed (**isovels,** dotted on the charts). The streamlines are everywhere parallel to the wind flow and do not tell us anything about the wind speed, which is shown by the isovels, lines of constant wind speed. We can readily interpolate between observation points.

These two maps are actually idealized representations of a very complex flow pattern. The flow over the water is believed to be reasonably

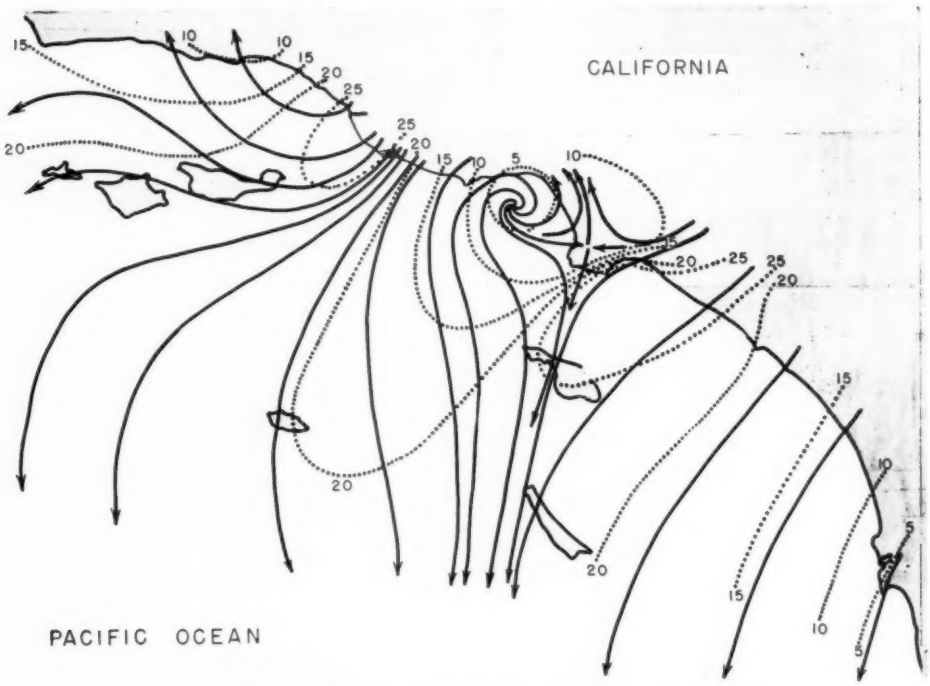


Fig. 1. Surface streamlines and isovels for 10:30 PST, January 3, 1949.

representative of the actual large-scale pattern. The flow over the land area is completely idealized and the various small-scale eddies and jets down individual canyons are not shown. The major jets through the Santa Clara and Santa Ana river valleys are shown roughly, and the flow agrees with the limited number of observations plotted. Additional observations would show a more complex pattern.

The dust lifted by a Santa Ana lowers visibility to an important extent, and pilots usually report the top of the dust as 8,000, 9,000, or even 10,000 feet over the Los Angeles basin during a Santa Ana storm. The moderate to severe turbulence reported by pilots for the lower elevations would confirm the degree of mechanical turbulence, whereas there is a lack of turbulence at the higher elevations. Above these limits the air is ordinarily smooth and visibilities are unrestricted. The turbulence over the mountains can be expected to extend to higher elevations than over the Los Angeles basin. Considering many cases, this difference in elevations would average about 2,000 feet.

In and adjacent to the national forests of southern California, the largest and most disastrous fires are associated with the Santa Ana. Extremely low humidities are experienced both day and night, often for several days, resulting in a very high fire hazard. During Santa Ana conditions, some weather stations have reported humidities as low as one per cent. Drying takes place initially over the ridges and in high passes. Gradually, adjacent areas are affected in a similar manner, with the eventual result of high temperatures and very low humidities generally over southern California.

The U. S. Forest Service uses a fire index rated on a meter having as factors the amount of precipitation, wind velocity, relative humidity, temperature, and the conditions of the vegetation. The range of the scale on the meter is from **low** to **extreme.** As the wind velocity and relative humidities are given considerable weight in the computation of this index, Santa Ana winds bring readings of **extreme** on the meter. A continuation of these conditions for several days makes the problem of controlling a "going" fire a difficult task. Local forestry men and weather forecasters also recognize the fact that during these prolonged periods record heat waves or high temperatures may readily occur.

The Santa Ana must be considered as very important in many ways, in addition to its effect on the fire hazard. Structures may be blown down, automobiles sandblasted, discomfort caused by inhaling dust and by the drying effect on mucous membranes, trees and crops dam-

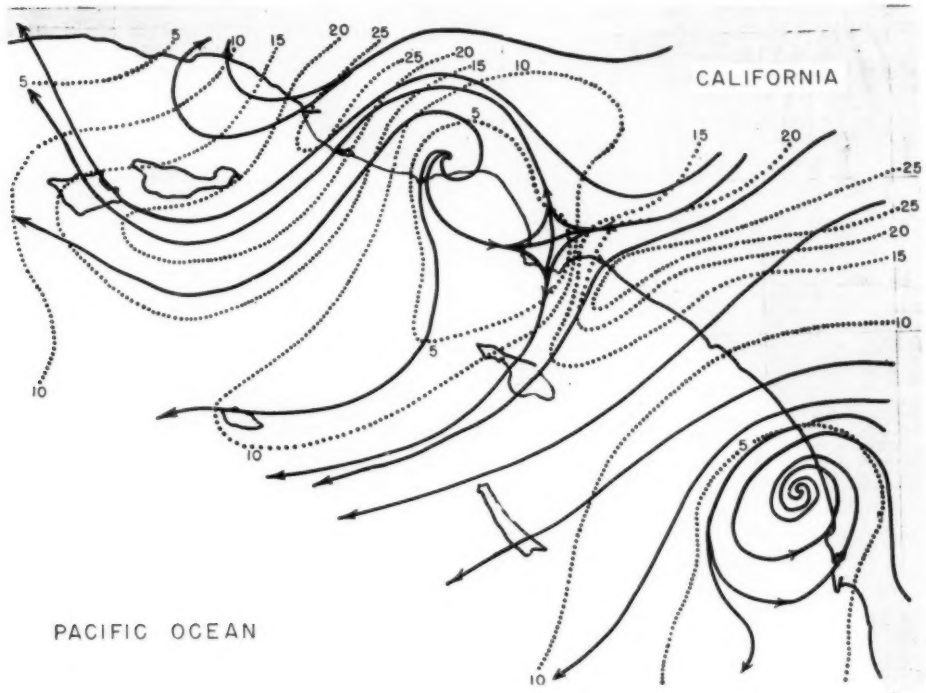


Fig. 2. Surface streamlines and isovels for 10:30 PST, November 3, 1950.

aged, and transportation of all types disrupted.

When barometric gradients are sufficiently large and offshore, resulting from a high pressure area over the Nevada plateau and adjacent areas, this wind can be expected to occur. In some borderline cases, the northeasterly winds are smooth and of comparatively low speed; since they do not work their way down to the surface of the Los Angeles basin they leave the humidities in the cool, stable layer unaffected. Many of the Santa Ana winds that affect the high mountain levels and passes do not hit downtown Los Angeles or its vicinity.

During the summer the thermal low is well developed over southern California and contiguous land regions. This condition, in combination with the persistence of the Pacific high cell offshore, gives an onshore flow of air for most of the summer. It is apparent that in the summer the Santa Ana storm is a rarity. This is reflected by the graph of Fig. 3, which shows that certain months of the year have a greater frequency of Santa Ana occurrences.

The problem of forecasting a Santa Ana wind consists primarily of considering the surface pressure gradient and the distribution of temperatures aloft over the Pacific Southwest. If one waits until a sufficiently large pressure gradient and a large positive temperature difference in the upper levels between the coast and the Nevada plateau are established, it may be too late to catch the beginning of many a Santa Ana.

In order to overcome this weakness in forecasting, an objective system has been formulated that takes into consideration the advection of cold air aloft over the Great Basin. This feature, accompanied by ridging aloft over the northern California coastal area, is correlated with a surface pressure gradient (Medford, Oregon, to Ely, Nevada). When the surface isobars and the upper-level height lines at 500 millibars are in phase, the occurrence of a Santa Ana can be expected after a lag of 24 hours.

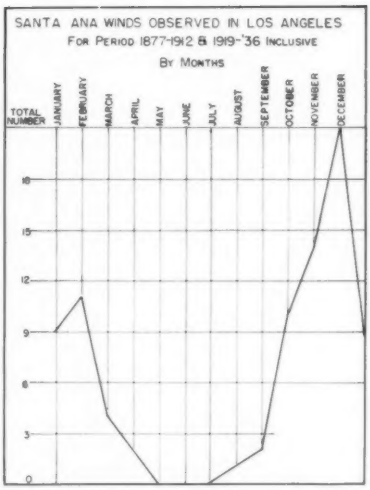


Fig. 3. Plotting the occurrence of Santa Ana winds at Los Angeles by months reveals the much higher incidence of this particular type of storm during the winter months than in the summer. The material was compiled from the log of Santa Anas of the Los Angeles Weather Bureau Office.

The maps of Fig. 4 are devised to show the rapid change in the isobaric pattern that takes place from a day before a Santa Ana to the day the wind occurs. These are composite maps prepared from 10 actual cases.

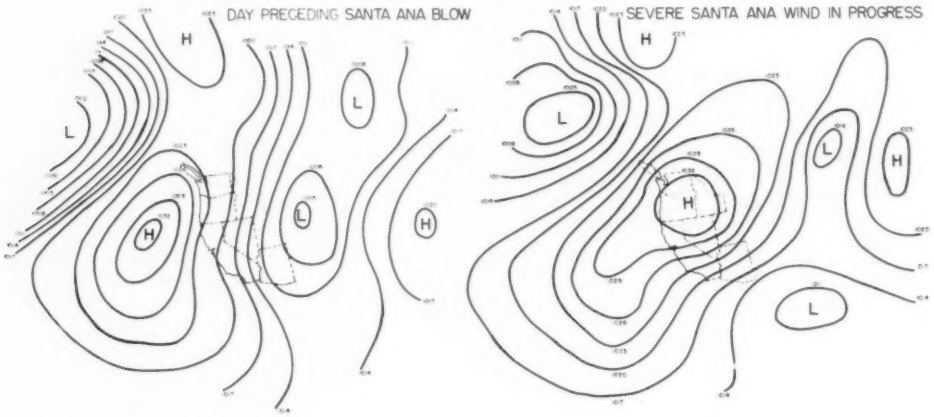


Fig. 4. The two charts are composite maps compiled from the data of 10 actual Santa Ana occurrences, and show the typical rapid change in the weather pattern from the day before to the day of the wind. The western states shown in dashed lines indicate the scale of the maps.

A Rare Halo Spectacle Seen in Iowa

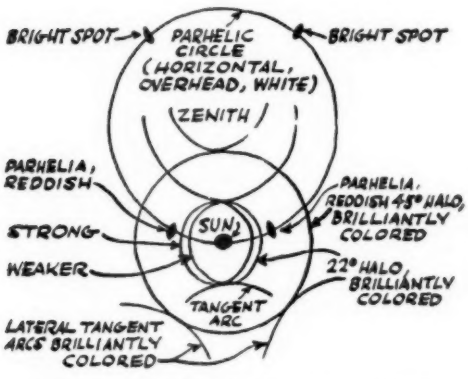
R. A. ROGERS, IOWA STATE TEACHERS COLLEGE, CEDAR RAPIDS, IOWA

ON FEBRUARY 27, 1952, conditions apparently were well-nigh perfect in the Cedar Falls-Waterloo area of Iowa for a fine and unusual display of solar halos. Portions of the phenomenon were also visible in less detail throughout a large portion of Iowa and as far north and east as Madison and Beloit, Wisconsin. It was, in my judgment, the most magnificent and extensive sky spectacle of its kind in this part of the country in the century.

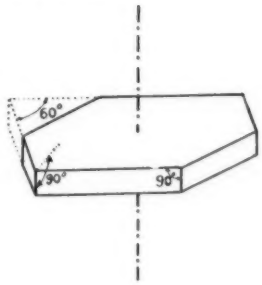
From about 11 a.m. until 2 p.m., while the sun was at its highest and the sky was just faintly murky with very thin cirrus clouds, almost every part of the famous Petersburg halo of July 18, 1794 (Humphreys' **Physics of the Air**, second edition, page 496), was in full view and persisted with almost no interruption for nearly three hours. The accompanying sketch was drawn while making observations from the back yard of my home just about noon on February 27th.

Both halos—complete—were present, with the most pronounced coloration I have ever witnessed. High overhead, with center at the zenith, was a glorious white circumzenithal circle with no gaps. Within this were portions of two other arcs, of whose identity I am as yet not quite certain. However, they were plainly visible, and there can be no doubt of their existence. The two brilliant sun dogs (parhelia) were displaced outward from the intersection of the smaller halo and the parhelic circle in a manner which this observer had never before witnessed. It has since been learned that this displacement depends on the altitude of the sun, becoming greater with the sun's increasing elevation. Both parhelia were strongly colored reddish on the inside and intensely white on the outside.

The smaller halo had a peculiar double structure. This was apparently due to the fact that, in reality, it was the combination of a regular, circular 22° halo and merged upper and lower tangent arcs. These formed an outer enclosure curve which was approximately elliptical in shape, a phenomenon also associated with the elevation of the sun. Our observation in Cedar Falls conforms most closely to diagrams shown on page 504 of Humphreys' book.



The author's sketch of the forms observed in the complex halo of February 27, 1952.



A schematic drawing of a thin ice-crystal plate, showing the various angles. The principal axis is dotted.

Both lateral tangent arcs below and to the right and left, respectively, were present and so strongly colored that they looked like rainbows. Behind the observer and away from the sun about 120° on either side were two brilliant spots, known as 120° countersuns. No coloration was involved.

The general causes of such a solar spectacle are well known to students of atmospheric optics. It is the cirrus clouds, consisting of tiny floating ice crystals very high in the air, which do the trick. The typical shape of these crystals is the hexagonal prism — like a slice out of a six-sided pencil. The arrangement of circular halos, arcs, and bright spots depends on the orientation of the ice crystals floating in the air and the particular manner in which the sunlight strikes them. As the crystals have six sides, two ends, and an abundance of 60° and 90° angles between surfaces, there is a great variety of optical phenomena which may occur.

The colored halos result from the refraction, or bending, of light rays passing through thousands of the tiny little prisms. The lateral tangent arcs owe their rainbow-like characteristic to a similar cause. The white parhelic circle, parallel to the horizon and passing through the sun, results from the reflection by these thousands of tiny ice crystal surfaces. The parhelia of 120° are due chiefly to two total reflections within hexagonal crystals, across an internal angle of 120°, first from the one and then the other of two adjacent columnar faces.

ED. NOTE: The reader may also refer to an article by Hans H. Neuberger, "Halos," in WEATHERWISE for August, 1951, for a discussion of some of the varied halo forms, and a report on a halo observing program for amateur weathermen.

200 MILES UP

J. Gordon Vaeth. Ronald Press Company, New York, 1951. 207 pages. $4.50.

THIS TITLE, although somewhat premature at present, is that of a book on the measurement of phenomena in the upper atmosphere, mainly by direct probing techniques. It is intended as a semipopular treatise, and several of the chapters are certainly sufficiently lucid and descriptive for reading by the general public.

The chapter on the "Atmospheric Ocean" is especially well written, in that it gives an excellent summary of the knowledge available at the present time about the upper atmosphere, without going into too many technical details.

Chapter III, which in the opinion of this writer is the weakest in the book, describes rocket-borne instruments used by the Navy in its upper-air research program. It is difficult to see how the nontechnical person can follow the descriptions of the instruments from the photographs and brief reading material. To those versed in the subject, it suffers by its restriction to the Navy program alone; however, the material on rocket-borne cameras and the associated photographs taken from heights of 18 to 60 miles are very good.

A brief history is given of the development of the modern rocket from the experiments of Dr. Goddard to the launchings of the V-2 by the Germans. Then a chapter deals with the Skyhook balloon, and describes the techniques for obtaining upper-air data to about 95,000 feet.

Chapter VI describes operations at White Sands from the time the Tiny Tim rocket was fired in 1945 to the launching of V-2's, Aerobees, and Vikings. The author's discussion of the ground instrumentation is unusually good for a popular book, and includes illustrations of the sky screen and the phototheodolite. His description even includes locating the expended rockets, and other types of operations necessary on the day of rocket launchings.

One of the best chapters is VII, which in the space of 15 pages gives a popular illustrated account of the principles of rocket flight. The two chapters on the V-2 should give the average person a pretty good idea of this rocket and how it is fired. A good selection of topics has been made, important things being considered without spoiling the picture with too many trees. But the detail given (on pages 172-3) of a rocket launching is justified and is recommended to those readers who have never seen one fired.

Two American-made rockets, the Aerobee and the Viking, are discussed in succeeding chapters. The Viking is a guided missile somewhat similar to the V-2, whereas the Aerobee is a true rocket and must be launched from a tower. Illustrations are given of both rockets and the launching operations.

The writer is impressed on the whole by the style of the author, and recommends the book, not only for popular reading, but even to many of those who have been connected with upper-air rocket research.

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This second edition of a book which appeared in 1949, and whose first edition was soon exhausted, has had extensive revision. Its observational and theoretical discussions are thus well up to date.

Among the chapters are ones on the general circulation of the lower atmosphere, the upper atmosphere studied from rockets, the atmosphere above 300 km., geological evidence on the evolution of the earth's atmosphere.

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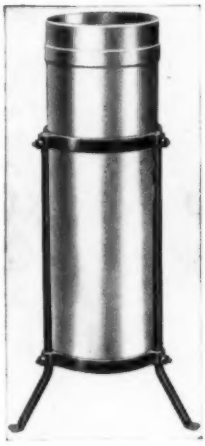

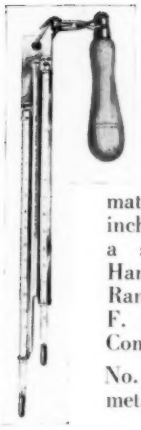

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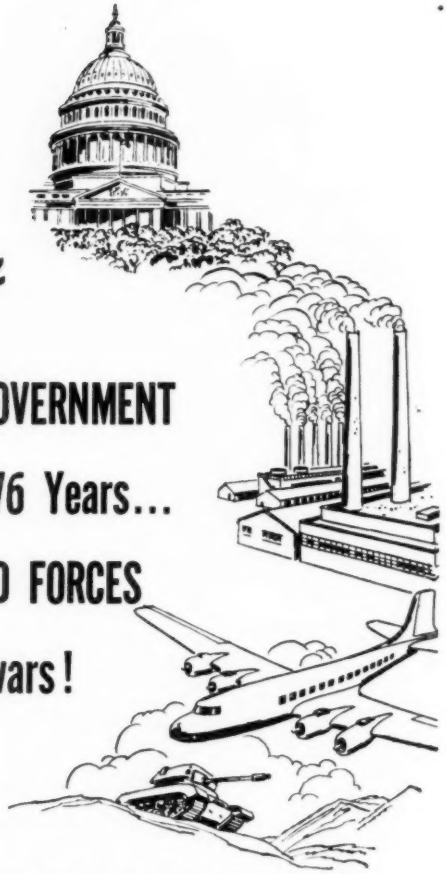

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